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Description

[0001] The present invention relates to a molecular vacuum pump, which allows for evacuating a gas from a vessel and for creating high vacuum in such vessel generally within 10 Pa to 10^{-6} Pa (0.1 mbar to 10^{-6} mbar), preferably, between 1 Pa and 10^{-4} Pa (10^{-2} and 10^{-6} mbar).

[0002] At present, when it is desired to maintain pressure of the order of 10^{-3} Pa to 10^{-5} Pa (10^{-5} to 10^{-7} mbar), for example, to evaporate materials in vacuum, or when it is necessary to maintain pressures of the order of 1 Pa to 10^{-3} Pa (10^{-2} to 10^{-5} mbar) in carrying out, e.g., a plasma process, molecular pumps are used, which allow for working within this pressure range. The required equilibrium pressure is obtained by balancing the pumping system gas admission flow with the discharge flow of the pumping system at a certain level. The pump pumping rate is generally fixed (volume per unit of time), and the pressure control obtains by adjusting the leakage rate in the vacuum chamber. It should be noted that since no gas is admitted, pressure does not decrease indefinitely, but it attains a certain level that is called the system limit pressure, which results in an equilibrium between the leakages inherent in any installation and the pumping rate of the installed pumping unit.

[0003] Two types of pumps are substantially used for the above-mentioned pressure range: on the one hand, so-called diffusion pumps, based on the entraining of the gas in the vessel in which vacuum has to be created by ejection of the gas by means of a plurality of concentric nozzles made integral with the pump casing, and, on the other hand, with rotary molecular entrainment pumps (turbomolecular pumps and "molecular drag pumps"), entraining gas molecules that collide with the pump rotor. The pumps of these two types both have substantial disadvantages.

[0004] In a diffusion pump, there are problems of contamination of the vessel in which vacuum has to be created, caused by re-diffusion of the pump vapor into the vessel because of the use of evaporating fluids such as hydrocarbons and silicones whose vapor is used as a pumping medium. In addition, the evaporation and condensation of the fluids results in a very high demand for energy and water. Moreover, a diffusion pump should be choked very strongly to function at a pressure above or equal to 10^{-3} mbar in the vessel to avoid strong pressure fluctuations and high degree of contamination of the vacuum chamber. In general, this choking imposes a string restriction upon the volumetric flow rate of the pump.

[0005] On the other hand, a rotary molecular pump is efficient only when the rotor speed is of the order of the gas molecule displacement velocity, thus requiring a very high rotation speed, generally, between 30,000 and 80,000 RPM

depending on the pump size. The rotor end can attain the maximum velocity of the order of 500 m per second for molecular pumps only at such rotation speeds. As a matter of fact, a speed increase does not come all that easy because of mechanical problems that are hard to overcome. At such speed, the rotor, which is normally made of aluminum alloy, undergoes high stresses of up to 150 N/mm². It is, therefore, very important, in order to avoid rotor collision with the stator, to assure a perfect rotor alignment (to micron precision) and balancing by using advanced dynamic balancing techniques in vacuum at nominal speed. For this reason, machining and especially balancing are very costly components of the primary cost of a rotary molecular pump. Among all problems related to utilization of a rotary molecular pump, there are more specifically, the following:

- Strong wear of mechanical parts generally requires the use of very expensive magnetic bearings or gas bearings;
- In case mechanical bearings are used, lubricant utilization may be conducive to contamination in the vessel, which, even if it is negligible compared to what is obtained with a diffusion pump, can prove critical in certain applications;
- In the presence of a magnetic field over 10 mT, the use of rotary molecular pumps with a conducting rotor is very complicated because of the induced currents that cause overheating of the rotor;
- An increase in rotation speed of the pumps of this type is difficult and expensive with a capacity above 5000 l per second because of tooling for machining and balancing of the pumps.

[0006] One of the important objectives of the present invention is to provide a molecular pump, which allows for eliminating disadvantages inherent in the existent pumps of this type.

[0007] With this in view, the invention provides a pump having the features defined in claim 1.

[0008] The above-mentioned members advantageously cooperate with means that allows for applying to them vibrations having a component directed toward the outlet port.

[0009] In one preferred embodiment of the pump according to the invention, the above-mentioned member comprises a piezoelectric material, which is attached to the above-mentioned support and is coated on the side opposite to the side facing toward the support with an electrically conducting coating, with means being provided to apply alternating voltage to the member in such a manner as to impose upon the piezoelectric material a deformation in the direction transversal with respect to the support, hence to impose

corresponding vibrations upon the support.

[0010] Other features and advantages of the pump according to the invention will be apparent from the description given below as a non-limiting example of some specific embodiments of the pump, with reference to the accompanying drawings.

[0011] Figure 1 is a schematic view, in longitudinal section along line I-I in Figure 2, partially in section, showing the first embodiment of the pump according to the invention.

[0012] Figure 2 is a cross-sectional view taken along line II-II in Figure 1.

[0013] Figure 3 is an enlarged cross-sectional view of the major part of the pump in the first embodiment.

[0014] Figure 4 is a modified form of the first embodiment shown in Figure 3.

[0015] Figure 5 is schematic view, in longitudinal section similar to that shown in Figure 1 of a second embodiment of the pump according to the invention.

[0016] Figure 6 is a schematic view, in longitudinal section similar to that shown in Figures 1 and 5 of a third embodiment of the pump according to the invention.

[0017] Figure 7 is an enlarged view showing a detail of Figure 6.

[0018] Figure 8 is a detailed view of the first modification of the embodiments shown in the foregoing figures.

[0019] Figure 9 is a detailed view of a second modification of the embodiments shown in the foregoing figures.

[0020] In the various figures, the same reference numerals are used for similar or identical parts.

[0021] The invention relates to a new type of a vacuum pump mainly designed for pumping within the pressure range between 10 Pa and 10^{-6} Pa (0.1 mbar and 10^{-6} mbar). This is, therefore, a pump that functions on the molecular principle, more specifically, a pump in which collisions of molecules with the pump walls strongly prevail over collisions between the molecules.

[0022] The first embodiment of the pump of this type is shown in Figures 1 and 2. The pump has a tightly sealed metal casing or frame 1 having an inlet port 2 in one of its sides, connectible to a vessel (not shown) in which high vacuum has to be created. An outlet port 3, which is connectible to a discharge pump (also not shown), is provided in the opposite side of the casing 1.

[0023] A plurality of accelerating members 4 are distributed in the interior space of the casing 1, which extend between the two ports 2 and 3 and which are spaced at a certain distance from each other at fixed locations, with passages 10 defined between them for gas being evacuated.

[0024] According to the invention, the members 4 are such as to impose upon gas molecules that originate from the

above-mentioned vessel and get in contact with the elements 4 a velocity having a component directed toward the outlet port 3.

[0025] The elements 4 are the active parts of the pump, and they are arranged in successive stages. They allow for pumping gas from the inlet port 2 toward the outlet port 3, raising the gas pressure moving from one stage to another. This is achieved by imposing upon gas molecules at each stage a sequence of deceleration followed by acceleration under the effect of the members 4 of the former stage toward the members of the next stage.

[0026] Therefore, the molecular pump according to the invention should have a high pumping rate at the stages located closer to the inlet port 2 and a lower pumping rate at the stages that are located closer to the outlet port 3 where pressure will be hence at the highest level.

[0027] As a matter of fact, under steady conditions, the mass flow is constant in each stage of the pump, or, in other words, the product of the pumping rate by pressure is constant throughout the stages.

[0028] To allow gas pressure to increase from one stage to another, it is necessary that the pumping rate decrease in proportion, which in practice results in the cross-sectional area of the passage 10 for gas decreasing from one stage to another in the direction toward the outlet port 3.

[0029] For this reason, according to the invention, so-called "high-pressure" pumping stages, which are located in the proximity to the outlet port 3, are narrower than so-called "low-pressure" pumping stages, which are located in the proximity to the inlet port 2.

[0030] Preferably, the above-mentioned members 4 are mounted on a fixed support 5 on the side thereof facing toward the outlet port 3, and they are made in such a manner as to cooperate with means 9 for applying vibrations having a component directed toward the outlet port 3.

[0031] In addition, means is provided to keep the support 5 at a reduced temperature, e.g., at an ambient temperature.

[0032] For that purpose, the support 5 and the casing 1 are made of a calorific material, more specifically of metal and are connected in a heat conducting fashion to each other and to a cooling circuit 8, which is supplied, e.g., with water surrounding the casing 1.

[0033] Each member 4 has a vibrating device 6, which in the embodiment shown in Figure 1 is made of a piezoelectric material attached to the metal support 5 and coated on the side opposite to the side facing the support 5 with a coating 7 of an electrically conducting material.

[0034] The means 9, which is an AC voltage generator, more specifically a sinusoidal voltage generator, is provided to impart to the layer of the piezoelectric material 6

deformations transversal with respect to the support 5, hence to impart corresponding vibrations to the coating 7.

[0035] The surface of the coating 7 subjected to these transversal vibrations imparts a velocity to gas molecules substantially in the pumping direction, thus acting actually as the rotor of a turbomolecular pump.

[0036] In order that pumping occurs with a good pressure ratio, the molecules that are excited in the above-described manner should be decelerated before they pass from the stage to the next stage where they will be accelerated again. This deceleration occurs when the excited molecules collide with the parts of the support 5 that are not subjected to vibrations and which are kept at a substantially reduced temperature as described above.

[0037] In order for the molecular pump according to the invention to function with maximum efficiency, the support 5 should be fixed to the pump frame, i.e., with respect to the casing 1, and only the surface 7 can be subjected to the transversal vibrations under the effect of the intermediate layer 6, which is preferably made of a piezoelectric material.

[0038] Vibration frequency and amplitude are interrelated because the velocity of displacement of the surface 7 should attain at least the order of a so-called "thermal" velocity of gas molecules under these pumping conditions.

[0039] Thus, for nitrogen pumping, at a temperature of 25°C, it is preferred that the velocity be of the order of 500 m/s. This corresponds to a pulsation of 500 krad/s with amplitude of 1 mm, a pulsation of 5 Mrad/s with amplitude of 100 nm, or a pulsation of 50 Mrad/s with amplitude of 10 µm.

[0040] the functioning principle can vary depending on pulsation (or which is the same, on frequency) and on the amplitude of displacement of the vibrating surface 7.

[0041] Instead of using a piezoelectric material for making the vibrating device 6, it can be made, e.g., as an electromagnetic device having an electromagnet or an electrostatic device in which the support 5 and the surface 7 define together a capacitor to which AC voltage is applied or a magnetostriction transducer.

[0042] In the case, however, where the intermediate layer 6 between the support 5 and the surface 7 is made of the piezoelectric material, for example, as used in the embodiment shown in Figures 1 and 2, relatively high frequencies can be obtained, e.g., the resonance frequency of the piezoelectric material that is used. Thus frequencies of the order of 20 MHz can be achieved when lead zirconates and titanates (LZT) are used as piezoelectric materials, and the frequencies may be above 100 MHz using PVDF type polymers.

[0043] According to the invention, polymeric piezoelectric materials, more specifically, the above-mentioned polymers, are of particular interest because of their low acoustic impedance ($4 \cdot 10^6 \text{ kg}^{-2}\text{s}^{-1}$), which allows the surface 7 to be vibrated without imparting vibrations to the support 5, which is kept at a relatively reduced temperature.

[0044] As mentioned above, as a result of an increase in pressure of the gas being pumped, moving toward the outlet port 3, it is necessary to adapt the cross-sectional area of the passage 10 from one stage to another as well as the distance between the successive stages to conform to a decrease in the average free flight path between elastic collisions of the molecules being pumped in order to stay within the molecular operating conditions.

[0045] For example, at a nitrogen pressure above or equal to 0.1 Pa (0.001 mbar), the characteristic dimension between the two stages is preferably maximum a few centimeters, and with a pressure of 1 Pa (0.01 mbar), this dimension becomes a few millimeters, and it will be even smaller for pressure of the order of 10 Pa (0.1 mbar).

[0046] For this reason, among other things, different types of geometry and position of the supports and vibrating elements 4 can be considered for constructing different pump stages.

[0047] First of all, as regards the first embodiment shown in Figures 1 and 2, which is one of the preferred configurations, the airtight casing 1 in which the vibrating elements 4 are provided has a square or rectangular cross-sectional shape as shown in greater detail in Figure 2, and the metal supports 5 are positioned in successive stages and in staggered fashion in the casing. The supports are made as plates extending in parallel to each other between two opposed walls of the casing 1. The plates that define the supports 5 are cooled by thermal contact with the walls of the casing 1. The plates extend in parallel planes, each defining a stage. Within each stage, the plates extend at a certain distance from each other to allow gas to pass from one stage to another.

[0048] The bottom side of each of the support plates 5 is coated with PVDF piezoelectric film, which is connected to an oscillating circuit 9 as shown in greater detail in Figures 3 and 4, assuring vibrations of the film preferably at a frequency close to the resonance frequency.

[0049] Because of its low mass and low acoustic impedance in comparison with those of the support plates 5, the exposed surface of the PVDF film vibrates while the support remains stationary. The surface is coated with the metal coating 7, which assures polarization of the film and also imparts the kinetic energy to gas molecules and atoms, which absorb it in transverse direction with respect to the coating 7

and in the direction toward the outlet port 3, i.e., in the pumping direction as shown by arrow 11.

[0050] As mentioned above, the PVDF film is excited electrically by means of an oscillating circuit. In the embodiment shown in Figure 3, the oscillating circuit comprises an AC voltage generator 9', which is connected by means of the conducting coating 7 deposited over the piezoelectric film 6 and on the other hand, the metal support 5.

[0051] In the embodiment shown in Figure 4, the piezoelectric material 6, for which the direction of initial polarization is shown by arrow 6', is inverted from one layer to the other. The layers 6 are coated with an electrically conducting film 7 that allows the layers to be connected independently to the ground and to the AC voltage generator 9. This configuration has a substantial advantage because it assures the following:

- Maintain connection to ground of the support 5 as well as the external surface 7 that imparts vibrations to the molecules;
- With a predetermined value of the electric field that is applied, this configuration allows for operating under lower nominal voltages for active thickness values that are theoretically as big as necessary because the field is applied to the successive layers;
- This configuration allows for operating with any active thickness at high frequencies close to the resonance thickness of the component layers 6, bearing in mind that the resonance thickness increases with a decrease in thickness of the layer 6.

[0052] The PVDF film can be either in direct contact with the support 5 if the latter is an electrical conductor, or it may be coated with a conducting film if the support 5 is not an electrical conductor.

[0053] Figure 5 presents a second embodiment of a preferred configuration of the vibrating elements 4 in the casing 1.

[0054] In this configuration, the first stages of the pump, or those that are located in the proximity to the inlet port 2, are inclined with respect to the longitudinal axis of the casing 1 at an angle of the order of 45° in order to raise the pumping rate.

[0055] In the subsequent zones of the casing 1, this angle decreases further in such a manner that the stages become narrower to become horizontal in the proximity to the outlet port 3. The objective is, as explained above, that the pumping flow at the beginning be relatively high with a relatively low pressure, with the pump flow rate decreasing and the pressure increasing moving along the casing because

of conservation of the mass flow throughout all stages of the pump under steady conditions

[0056] In Figure 5 there are four zones of stages 12, 13, 14, and 15. In each one of them, the supports are mounted in a predetermined position.

[0057] Figure 6 shows a third preferred configuration of the shape and position of the supports 5 and vibrating elements 4. Figure 7 shows a detail of the same figure.

[0058] In the zone 12, in the proximity to the inlet port 2, the supports 5 are positioned in staggered fashion and have their transversal section substantially in the form of an isosceles triangle with the vertex directed toward the inlet port 2. As it can be better seen in Figure 7, inclination of the oblique sides 16 of the supports is such as to assure the maximum reflection of the gas molecules that are hitting these sides toward the base 17 of the supports, which has the vibrating element 7, as shown by arrows 18. In addition, in this first zone 12, the distance between the supports 5 is at its maximum in order to define the passage 10 which has the maximum size for the molecules reflected by the stage for moving toward the next stage of vibrating elements. In the next stages, the stages become closer to each other, and the cross-section of the passage 10 becomes smaller. In addition, the height of the triangular supports 5 also decreases, and the inclined sides 16 have a concave shape, whose curvature depends on the size of the passage 10 so as to transmit the maximum quantity of molecules to the next stage.

[0059] An important feature of the configuration presented in Figures 6 and 7 is the presence of vibrating elements 19 similar to elements 4, which partly cover the inclined sides 16 of the supports 5. The elements 19 are made of an intermediate layer 21, which is preferably made of a piezoelectric material coated with a conducting coating 20, and they are partly opposed to the elements 4 of the preceding stage. The elements 19 allow for imparting the kinetic energy to molecules during a number of successive collisions with the vibrating elements, rather than at a single collision, thus driving the molecules toward the passage 10 and allowing admission to the next stage. At the next stage, the kinetic energy of the excited molecules decreases as a result of collisions with the parts of the inclined sides 16 that are not covered with the elements 19, which also gives rise to a pressure increase at this stage (P2) with respect to the pressure obtaining at the preceding stage (P1).

[0060] The non-covered parts of the supports of a given stage preferably correspond to a projection of the surface of the passage 10 between two consecutive supports of the preceding stage on the inclined sides 16 of the supports of that given stage. This is shown by projection lines 22 in Fig. 7.

[0061] A substantial advantage of this configuration is that the kinetic energy necessary for pumping molecules is imparted at a plurality of steps, so that practically it become possible to use the values of the product of pulsation by amplitude of vibrations that are below 500 m/s.

[0062] It is, therefore, possible to increase the compression ratio from one stage to the other compared to the use of purely triangular section supports.

[0063] Other modifications of the configuration of the supports 5 and vibrating elements 4 can be used.

[0064] More specifically, the base of the triangle may be curved to be either concave or convex. In addition, the vibrating element 4 can be subjected to amplified deformation during its vibrations and change in the alternating fashion from a concave or planar shape to a convex or concave shape, thus assuring an increase in the vibration amplitude. In this case, the vibrating element can be made as a flexible plate attached with its two ends to the support 5 to be deformed, under the effect of the oscillating circuit 9 from a substantially planar condition in the state of rest to a curved condition in the excited state as shown in Figure 8.

[0065] In still another configuration, the vibrating element 4 can be made as a piezoelectric plate fixed at a point 23 to the support 5 to be displaced, under the effect of the oscillating circuit 9, between the rest condition and a deformed condition, similar to a bimetal plate. This embodiment is shown in Figure 9.

[0066] In Figures 8 and 9, the condition in the excited state is illustrated with dotted lines.

[0067] An example of concrete realization is given below to illustrate further the subject matter of the invention.

[0068] The example deals with a molecular pump of the type shown in Figure 6, having 30 superposed horizontal stages, in which the supports 5 of the vibrating elements 4 are positioned in staggered fashion. Each of the supports 5 has the following transversal dimensions: 700 mm x 15 mm, and they are distributed within the casing having a rectangular horizontal cross-sectional size of 700 mm x 600 mm.

[0069] Each stage is made up of 20 rectangular supports 5 of triangular configuration positioned in the manner similar to that shown in Figure 6.

[0070] The supports 5 are cooled by thermal contact with the side walls of the casing 1 of the pump, which is in turn cooled with the deformations transversal water circuit 8.

[0071] PVDF film 6 is attached to the lower surface 17 of the supports and partly faces toward PVDF films 20 attached to the part of the sides 16 of the supports 5 of the next stage. The piezoelectric films, which are excited at a frequency close to their resonance frequency of the order of 10 MHz,

allow a compression ratio of 2 to be obtained between the pump stages for a gas formed of nitrogen. This allows for obtaining the maximum compression ratio of 10^9 for the above mentioned 30 stages of the pump. The nominal rate is 24,000 l/s for nitrogen at 25°C, and the maximum mass flow obtained is 24 mbar.l. sec⁻¹ or 86.4 mbar.m³/h.

[0072] With a nitrogen pressure measured at the inlet port 2 that equals 0.5 Pa ($5 \cdot 10^{-3}$ mbar), a pressure of the order of 3 Pa (0.03 mbar) is observed at the outlet port 3 at which a discharge pump "Roots" for 3000 m³/h is connected. Thus the compression ratio of this molecular pump is 6, with the pumping rate of 4800 l/s under these operating conditions.

[0073] It will be apparent that the invention is not limited to the above-described embodiments illustrated in the accompanying drawings, and modifications can be used, more specifically with regard to configuration of the supports and vibrating elements used in the airtight casing of the pump.

[0074] Thus, the support of a stage can be made as a plate having a perforated surface on the side facing the outlet port 3, the vibrating elements are attached [sic!].

[0075] In addition, the elements can be made as means of quite different types.

[0076] As a matter of fact, according to the invention, it is enough to provide within the airtight casing of the pump a succession of dipoles oriented from the inlet port toward the outlet port. In the above-described embodiments, the dipoles were formed by a fixed part and a vibrating part. It is also possible to provide a dipole formed of a cold part and a hot part, separated from each other by an insulator.

[0077] Finally, the casing 1 can be installed in different positions, e.g., the inlet port 2 can face down or to the side.

[0078] The casing 1 can also have geometries other than the prismatic one. Thus, for example, it could be cylindrical with a circular cross-sectional shape.

Claims

1. A molecular pump for evacuating gas from a vessel and for creating thereby high vacuum in the latter, comprising a substantially airtight casing (1) having an inlet port (2) in one of its sides and an outlet port (3) in the side opposed to that side, elements (4) being provided between the two ports (2) and (3) at a certain distance from one another on supports (5) fixed within said casing (1) for gas passage, characterized by the fact that said elements (4) are mounted on the fixed

- supports (5) on the side thereof that faces the outlet port (3) to define with the supports a succession of dipoles whose active parts, which are formed by these elements, are also directed toward the outlet port and to impart to gas molecules that originate from said vessel and get in contact with said elements an acceleration in the direction toward the outlet port.
2. The pump of claim 1, characterized by the fact that said elements (4) cooperate with means (9) which impart to them vibrations having a component directed toward the outlet port.
 3. The pump of any of claims 1 and 2, characterized by the fact that the support (5) is made of a calorific [sic!] material that is heat conducting and is connected to a cooling circuit, the support (5) thus defining the cold part of the dipole, the element (4) being separated from the cold part by an insulator, thus defining the hot part of the dipole.
 4. The pump of any of claims 1 through 3, characterized by the fact that said elements (4) are positioned in staggered fashion.
 5. The pump of claim 4, characterized by the fact that means is provided to keep said support (5) at a substantially reduced temperature, e.g., at the ambient temperature.
 6. The pump of claim 5, characterized by the fact that the support (5) and the casing (1) are made of a calorific [sic!] material and are connected to each other in the conducting manner, said means for keeping the support at a relatively reduced temperature comprising a cooling circuit (8) surrounding said casing (1).
 7. The pump of any of claims 4 through 6, characterized by the fact that said element (4) comprises a piezoelectric material (6) attached to said support (5) and coated on its side opposite to the side that faces the support with an electrically conducting coating (7), means (9) being provided to apply to the element (4) AC voltage in order to impart deformation to the piezoelectric material (6) in the direction transversal with respect to the support (5), thus imparting corresponding vibrations to said coating (7).
 8. The pump of claim 7, characterized by the fact that the surface of the piezoelectric material (6) that is

- in contact with the support (5) and the coating (7) are connected to the ground.
9. The pump of one of claims 7 or 8, characterized by the fact that the piezoelectric material (6) makes part of a flexible plate mounted on the support and subjected to elastic deformation under the effect of said AC voltage.
 10. The pump of any of claims 4 through 9, characterized by the fact that the supports (5) are positioned in staggered fashion and have the transversal section of an isosceles triangle with its vertex directed toward the side of the casing (1) in which the inlet port (2) is provided, the inclined sides (16) of the supports (5) being inclined in such a manner as to assure reflection of molecules hitting the sides toward the base (17) of the supports (5) of the preceding stage.
 11. The pump of claim 10, characterized by the fact that the inclined sides (16) of the supports (5) are at least partly concave.
 12. The pump of any of claims 4 through 11, characterized by the fact that the sides (16) of the supports (5) of a given stage that are oriented toward the supports (5) of the preceding stage are partly coated with elements (19) to which vibrations can be imparted, having a component directed toward the elements (4), which are provided on the side (17) of the supports of the preceding stage facing toward the outlet port (3), thereby increasing the kinetic energy of molecules as a result of a number of multiple collisions with the vibrating surfaces (7) of the elements (4) and (19) facing each other before going to the next stage.
 13. The pump of any of claims 7 through 12, characterized by the fact that the piezoelectric material (6) is comprised of quartz, Pochette salt ($\text{NaKC}_4\text{H}_4\text{O}_6\text{NH}_2\text{O}$), lithium sulfate ($\text{Li}_2\text{SO}_4\text{H}_2\text{O}$), lead methaniobate (PbNb_2O_6), lead titanate (PT), lead titanate zirconate (PZT), polyvinylidene fluoride (PVDF), copolymer of polyvinylidene fluoride and trifluoroethylene (P(VDF-TrFE)), copolymer of polyvinylidenetetrafluoroethylene fluoride (P(VDF-Te- FE)), or copolymer of vinylidene cyanide and vinyl acetate (P(VDCN-VAC)).

Patentansprüche

1. Molekularpumpe, welche dazu dient, ein Gas aus einem Behälter abzusaugen und dadurch in die-sem letzteren ein hohes Vakuum zu erzeugen, und welche umfasst: ein ausgesprochen dichtes Ge-

- häuse (1), das auf einer Seite eine Eintrittsöffnung (2), die für den Anschluss an das oben erwähnte Behältnis bestimmt ist, und auf der der oben erwähnten Seite gegenüber liegenden Seite eine Austrittsöffnung (3) aufweist, für die Durchleitung des Gases bestimmte Bauteile (4), welche zwischen diesen zwei Öffnungen (2) und (3) in einem gewissen Abstand voneinander auf in dem oben genannten Gehäuse (1) befestigten Halterungen (5) angeordnet sind, **dadurch gekennzeichnet**, dass die besagten Bauteile (4) auf den festen Halterungen (5) von der Seite dieser letzteren zur Austrittsöffnung (3) hin gerichtet dergestalt montiert sind, dass mit diesen Halterungen eine Folge von Dipolen festgelegt wird, deren aktive Teile, die von diesen Bauteilen gebildet werden, ebenfalls zur Austrittsöffnung gerichtet sind, und dass dadurch ermöglicht wird, den Gasmolekülen, die von dem oben genannten Behältnis kommen und mit diesen Bauteilen in Kontaktgeraten, eine Beschleunigung in Richtung auf die Austrittsöffnung zu erteilen.
2. Pumpe nach Anspruch 1, **dadurch gekennzeichnet**, dass die vorgenannten Bauteile (4) mit Mitteln (9) zusammen wirken, welche es ermöglichen, dass diese in eine Schwingung versetzt werden, die eine auf die Austrittsöffnung zeigende Komponente aufweist.
 3. Pumpe nach einem der Ansprüche 1 und 2, **dadurch gekennzeichnet**, dass die Halterung (5) aus einem wärmespendenden und wärmeleitenden Material gefertigt und an einen Kühlkreislauf angeschlossen ist, wodurch diese Halterung (5) den kalten Teil eines Dipols bildet, und dass das Bauteil (4) von diesem kalten Teil durch einen Dämmstoff getrennt ist und den warmen Teil des Dipols bildet.
 4. Pumpe nach einem beliebigen der Ansprüche 1 bis 3, **dadurch gekennzeichnet**, dass die vorgenannten Bauteile (4) in der Form der Fünf auf dem Würfel angeordnet sind.
 5. Pumpe nach Anspruch 4, **dadurch gekennzeichnet**, dass Mittel vorhanden sind, um die vorgenannte Halterung (5) auf einer merklich niedrigen Temperatur, beispielsweise auf Umgebungstemperatur, zu halten.
 6. Pumpe nach Anspruch 5, **dadurch gekennzeichnet**, dass die Halterung (5) und das Gehäuse (1) aus einem wärmespendenden Material gefertigt und miteinander leitend verbunden sind, wobei die vorgenannten Mittel, die zur Aufrechterhaltung der relativ niedrigen Temperatur der Halterung dienen, einen Kühlkreislauf (8) umfassen, der das oben genannte Gehäuse (1) umgibt.

7. Pumpe nach einem beliebigen der Ansprüche 4 bis 6, **dadurch gekennzeichnet**, dass das vorgenannte Bauteil (4) ein piezoelektrisches Material (6) enthält, welches an der vorgenannten Halterung (5) befestigt und auf der Seite, die der zur Halterung hin gerichteten Seite gegenüber liegt, mit einem elektrisch leitenden Überzug (7) bedeckt ist, wobei Mittel (9) vorhanden sind, um an dieses Bauteil (4) eine elektrische Wechselspannung in der Weise anzulegen, so dass dieses piezoelektrische Material (6) eine Verformung in einer zur Halterung (5) quer verlaufenden Richtung erfährt und folglich der oben genannte Überzug (7) in eine entsprechende Schwingung versetzt wird.
8. Pumpe nach Anspruch 7, **dadurch gekennzeichnet**, dass die mit der Halterung in Kontakt befindliche Fläche des piezoelektrischen Materials (6) und der Überzug (7) auf Masse liegen.
9. Pumpe nach einem der Ansprüche 7 oder 8, **dadurch gekennzeichnet**, dass das piezoelektrische Material (6) Bestandteil eines biegsamen Blattes ist, welches auf die Halterung montiert ist und eine elastische Verformung unter der Wirkung der oben genannten elektrischen Wechselspannung erleiden kann.
10. Pumpe nach einem beliebigen der Ansprüche 4 bis 9, **dadurch gekennzeichnet**, dass die Halterungen (5) in der Form wie die Fünf auf dem Würfel angeordnet sind und in Querrichtung einen Querschnitt aufweisen, der die Form eines gleichschenkeligen Dreiecks hat, dessen Gipfel in Richtung auf diejenige Seite des Gehäuses (1) gerichtet ist, in welcher sich die Eintrittsöffnung (2) befindet, wobei die schrägen Seitenkanten (16) dieser Halterungen (5) dergestalt geneigt sind, dass sie eine Reflexion der auf diese Seiten prallenden Moleküle zur Basis (17) der Halterungen (5) der vorhergehenden Stufe ermöglichen.
11. Pumpe nach Anspruch 10, **dadurch gekennzeichnet**, dass die schrägen Kanten (16) der Halterungen (5) wenigstens teilweise konkav sind.
12. Pumpe nach einem beliebigen der Ansprüche 4 bis 11, **dadurch gekennzeichnet**, dass die Seiten (16) der Halterungen (5) einer bestimmten Stufe, die zu den Halterungen (5) einer vorausgehenden Stufe hin gerichtet sind, teilweise mit Bauteilen (19) bedeckt sind, welche in eine solche Schwingung versetzt werden können, die eine Komponente aufweist, welche auf die Bauteile (4), die auf der Seite (17) der Halterungen der auf die Austrittsöffnung (3) zeigenden vorausgehenden Stufe vorhanden sind, gerichtet ist, und zwar dergestalt, dass ermöglicht wird, dass die Moleküle durch eine Reihe von Mehr-

fachstößen mit den schwingenden Flächen (7) der Bauteile (4) und (19), auf die sie vor ihrem Weitertransportzufolgenden Stufen zu, einen Gewinn an kinetischer Energie erfahren.

13. Pumpe nach einem beliebigen der Ansprüche 7 bis 11, **dadurch gekennzeichnet**, dass das piezo-elektrische Material (6) aus Quarz, Rochettesalz ($\text{NaKC}_4\text{H}_4\text{O}_6\text{NH}_2\text{O}$), Lithiumsulfat ($\text{Li}_2\text{SO}_4\text{H}_2\text{O}$), Bleimetaniobat (PbNb_2O_6), Bleititanat (PT), Bleitanzirkonat (PZT), Polyvinylidenfluorid (PVDF), Ko-polymer von Polyvinylidenfluorid und Tetrafluorethylen (P(VDF-TeFE)) oder Kopolymer von Vinylidenzyanid und Vinylazetat (P(VDCN-VAC)) besteht.

Claims

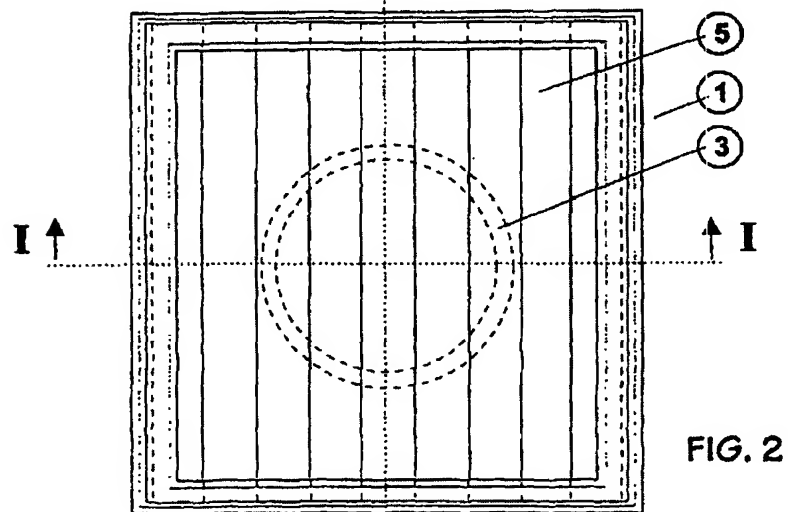
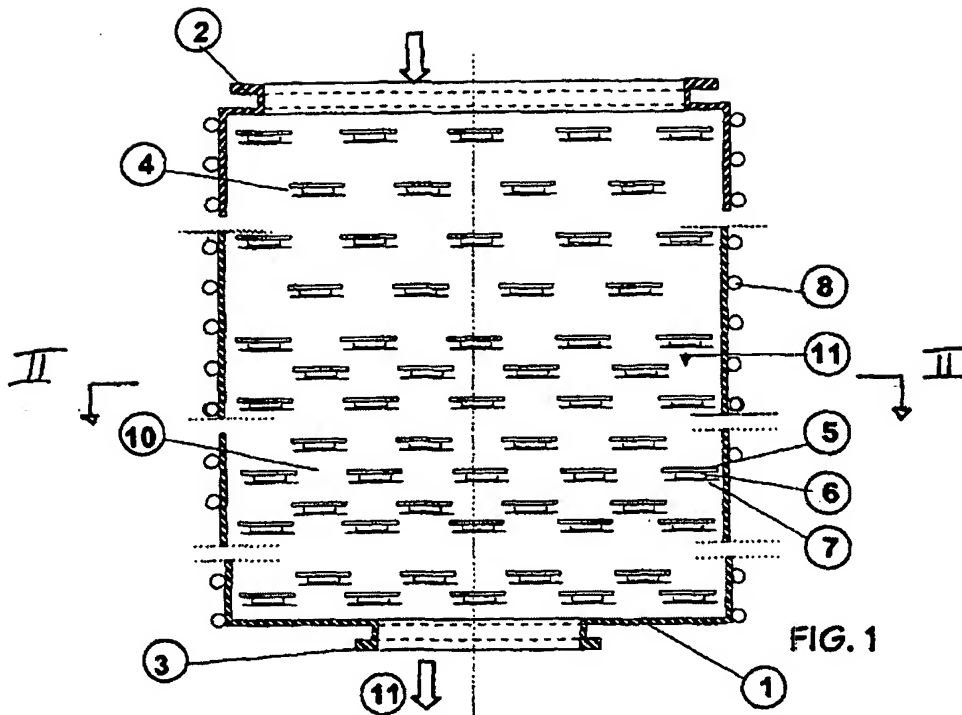
1. Molecular pump, which makes it possible to evacuate a gas from a chamber and to thus create a high vacuum in this chamber, that comprises a substantially sealed box (1) having on one of its sides an intake orifice (2) to be connected to said chamber and, on the opposite side, an outlet orifice (3), whereby elements (4) are mounted between those two orifices (2) and (3) at some distance from one another on supports (5) that are fixed inside said box (1) for the gas to pass through, **characterised in that** said elements (4) are mounted on fixed supports (5), on the side of the latter directed towards the outlet orifice (3), in a manner as to determine with these supports (5) a succession of dipoles, of which the active parts, formed by these elements, are also directed towards the outlet orifice, and to allow to impart to said gas molecules, coming from said chamber and entering in contact with these elements, an acceleration towards the outlet orifice.
2. Pump according to claim 1, **characterised in that** the said elements (4) co-operate with means (9) which make it possible to subject them to a vibration having a component directed towards the outlet orifice.
3. Pump according to any of claims 1 or 2, **characterised in that** the support (5) is made of a calorific and heat conducting material and is connected to a cooling circuit, in such a way that this support (5) is forming a cold part of a dipole and the element (4), being separated from this cold part by an insulating material, forming a hot part of the dipole.
4. Pump according to any of claims 1 to 3, wherein the above-mentioned elements (4) are provided in a staggered manner.
5. Pump according to claim 4, **characterised in that**

means are provided to maintain the above-mentioned support (5) at a relatively low temperature, for example the ambient temperature.

6. Pump according to claim 5, **characterised in that** the support (5) and the box (1) are made of a calorific material and are mutually connected in a conductive manner, whereby the above-mentioned means for maintaining the support at a relatively low temperature comprise a cooling circuit (8) surrounding said box (1).
7. Pump according to any of claims 4 to 6, **characterised in that** the above-mentioned element (4) comprises a piezo-electric material (6) fixed to the above-mentioned support (5) and coated, on the side opposite to the one which is directed towards the support, with an electrically conductive coating (7), whereby means (9) are provided to apply an alternating current to said element (4), such that said piezo-electric material (6) is subjected to a deformation in a direction transversal to the support (5) and, consequently, said coating (7) is exposed to a corresponding vibration.
8. Pump according to claim 7, **characterised in that** the surface of the piezo-electric material (6) which makes contact with the support (5) and the coating (7) are put to earth.
9. Pump according to any of claims 7 or 8, **characterised in that** the piezo-electric material (6) is part of a flexible blade mounted on the support and which can undergo an elastic deformation as a result of the effect of the above-mentioned alternating current.
10. Pump according to any of claims 4 to 9, **characterised in that** the supports (5) are provided in a staggered manner and represent a cross section which strongly resembles an isosceles triangle whose top is directed towards the side of the box (1) in which is provided the intake orifice (2), whereby the inclination of the oblique sides (16) of these supports (5) allows for a reflection of the molecules which hit these sides towards the basis (17) of the supports (5) of the preceding level.
11. Pump according to claim 10, **characterised in that** the oblique sides (16) of the supports (5) are at least partially concave.
12. Pump according to any of claims 4 to 11, **characterised in that** the sides (16) of the supports (5) of a specific level directed towards the supports (5) of a preceding level are partially covered with elements (19) which can be subjected to a vibration having a component which is directed towards the

éléments (4) provided on the side (17) of the supports of the preceding level directed towards the outlet orifice (3), such that the kinetic energy of the molecules is increased following a series of collisions with the vibrating surfaces (7) of the elements (4) and (19) which face one another before they pass on to the next level.

12. Pump according to any of claims 7 to 12, **characterised in that** the piezo-electric material (6) is formed of quartz, Rochelle salt ($\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$), lithium sulphate ($\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$), lead methaniobate (PbNb_2O_6), lead titanate (PT), lead zirconate titanate (PZT), polyvinylidene fluoride (PVDF), polyvinylidene fluoride and trifluoroethylene copolymer (P(VDF-TrFE)), polyvinylidene fluoride and tetrafluoro-ethylene copolymer (P(VDF-TeFE)) or vinylidene cyanide and vinyl acetate copolymer (P(VDCN-VAC)).



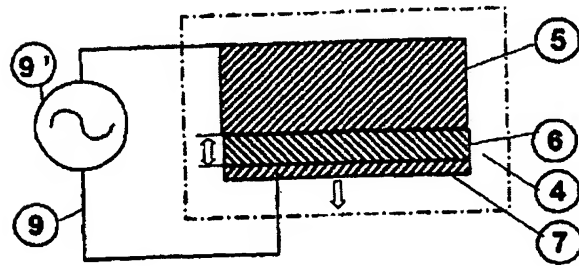
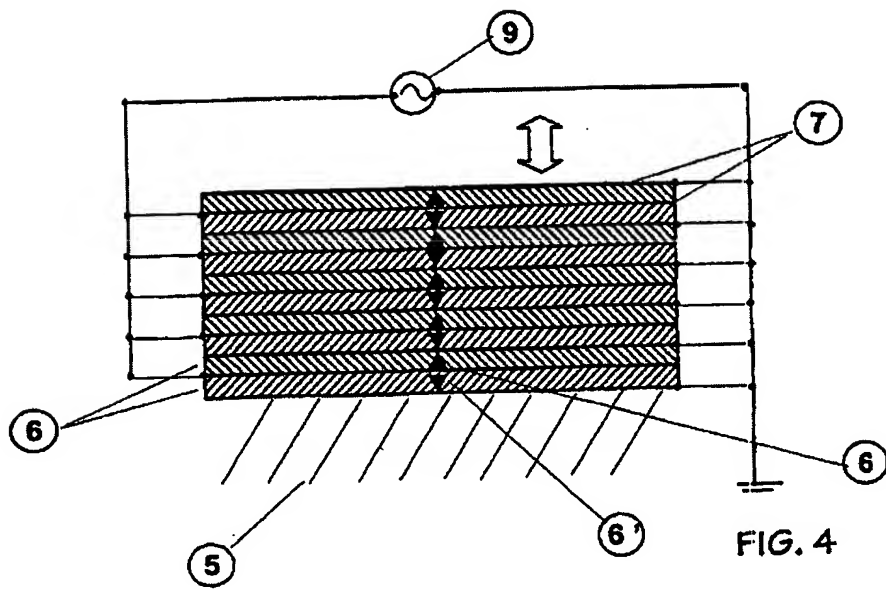
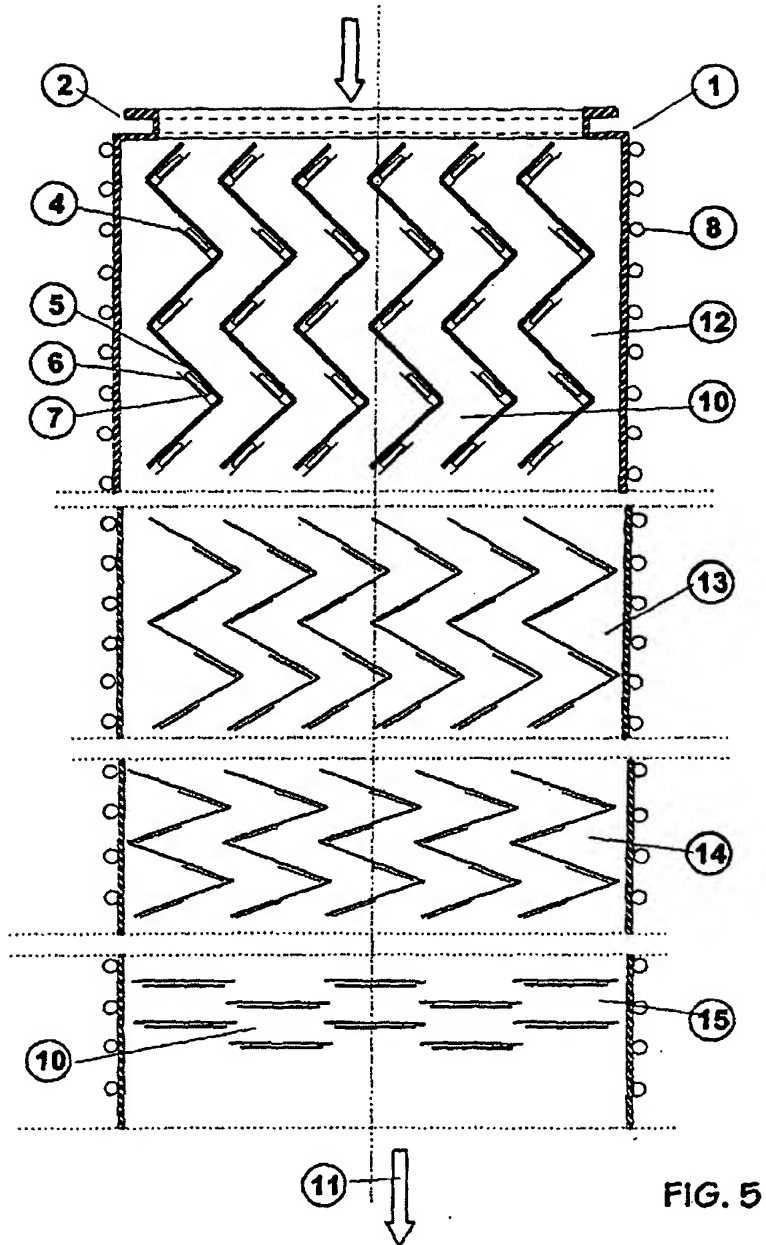


FIG. 3





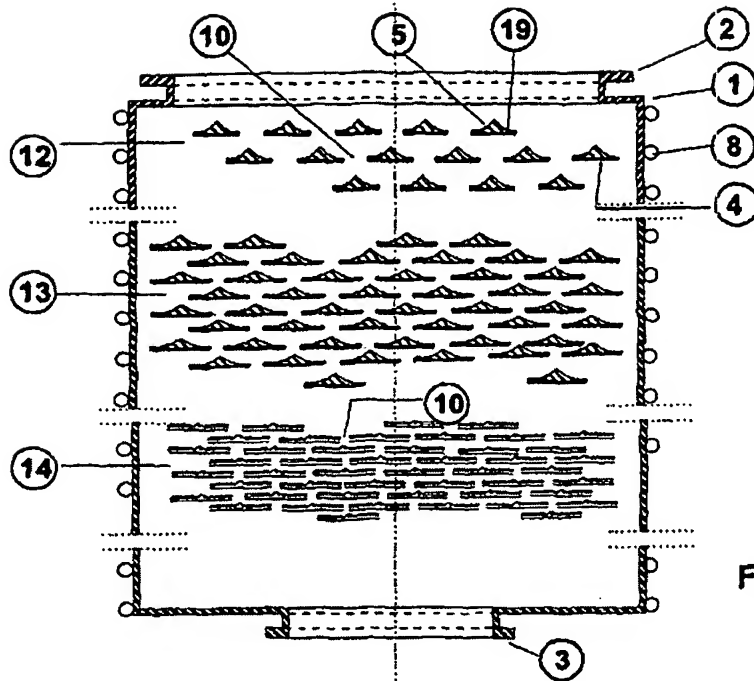


FIG. 6

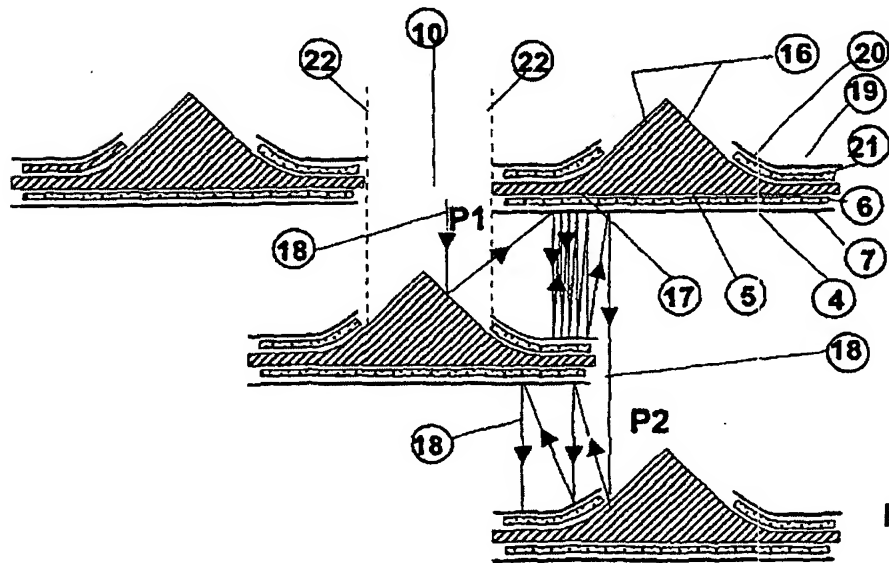


FIG. 7

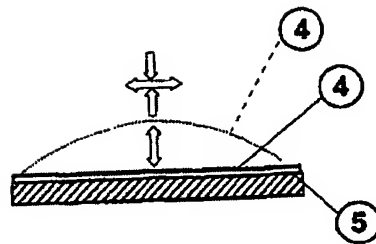


FIG. 8

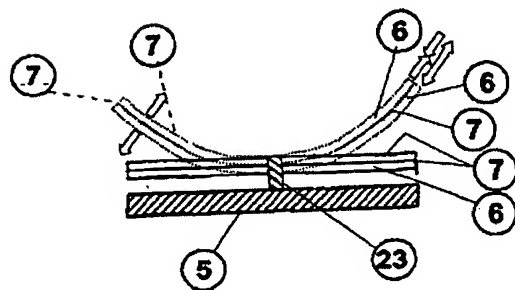


FIG. 9